Appendix 4. The Butterfield Light Rail Corridor Serving Sacramento

Executive Summary

Working Paper 1 (Subtask 1d, November 25, 1998) develops a theoretical and measurement framework within which the Mogridge-Lewis Convergence Hypothesis (MLC) can be employed in measuring the savings in highway delay attributable to transit and its equilibrating effect on the level of service in the corridor.

The framework also provides an MLC-based approach to making repeated measures of transit-induced savings in corridor delay without the need for repeated MLC surveys. The approach rests on the theoretical proposition, proven in Working Paper 1, that a stable and measurable relationship exists between roadway traffic growth over time and the inter-modal (highway-transit) equilibrium dynamics that give rise to delay savings in a congested corridor. In the absence of major changes in the level of highway supply or transit service in the corridor, this measured relationship, or model, provides a formula-based performance measurement system in lieu of a survey-based approach. In addition to the obvious cost advantages, this approach provides FTA with (i) an efficient means of measuring and comparing transit performance in strategic corridors; and (ii) a consistent performance assessment tool for transfer to MPOs throughout the country.

Purpose and Method

This Working Paper presents a case study of the methodology developed in Subtask 1c in application to the Butterfield-Sacramento corridor. The methodology consists of calibrating the MLC-traffic model with survey data. The model is then used to quantify delay savings attributable to light rail at present, and at alternative roadway traffic volumes (each for different user categories).

The study consists of four main steps:

1. Collecting highway travel data (traffic volume, distance, travel time, and vehicle occupancy in the corridor); and light rail ridership data along the corridor;
2. Conducting door-to-door travel time surveys and deriving the inter-modal convergence;
3. Estimating the "with transit" and "without transit" model and related curves and estimating the hours of delay saved due to transit; and
4. Quantifying delay savings by user category, namely, (i) light rail riders ("market" benefits); (ii) common segment users ("club" benefits); and, (iii) parallel highway users ("spillover" benefits).

The Butterfield-Sacramento corridor was selected to measure the performance of the light rail system connecting several residential areas with the Central Business District of Sacramento, California. MLC theory predicts that the improved transit system will attract modal explorers, reduce congestion, and improve roadway travel times. As a result, we would expect to see improvements in both highway and transit door-to-door travel times

Principal Findings

The case study finds that based on the MLC model calibrated with 1999 survey data, the magnitude of peak-period delay savings per trip due to transit is about 1.25 minutes per door-to-door trip (about 11 seconds per mile). These savings amount to

about 4 percent of total door-to-door journey times and align with reasoned expectations.

HLB estimated the hours of delay savings for three different user groups: Metro riders (market benefits), users of the US-50 common segment (club benefits), and users of parallel highways (spillover benefits). Table A 4.1 presents the estimated delay savings by category of user. Based on an assumed value of peak travel time of $15 per hour and an average of 250 working days per year. Table A 4.1 indicates aggregate peak delay savings due to transit of $7 million for 1999. The savings can be translated to $0.6 million per rail mile.

Table A 4.1 Benefits Summary for the Butterfield-Sacramento Corridor

	Daily Savings		Yearly Savings
Benefit Category	In Hours	In Dollars	In Dollars
Market	128	$ 1,920	$ 480,007
Club	1,269	$ 19,042	$ 4,760,480
Spillover	483	$ 7,247	$ 1,811,851
Total	1,881	$ 28,209	$ 7,052,338

The summary table shows that 67% of the savings are club savings while only 7% are market savings. These results illustrate the relative low ridership and the high use of automobile in the corridor.

Figure A 4.1 displays the "with-" and "without transit" curves using 1999 convergence data. The vertical difference between the "with-" and "without transit" curves represents the delay savings due to transit at different volumes of US-50 traffic. The curves indicate that in the absence of major infrastructure improvements or radical traffic growth, the performance metric will remain stable.

Although an intermodal travel time convergence of 15 minutes in this corridor is sufficient to yield delay savings to highway users (as compared to the "without rail" case), full convergence would of course yield even greater savings. The Mogridge-Lewis framework predicts that non-time related roadway travel costs (ie, the non-time elements of "generalized cost" such as parking costs, fuel costs and so on) account for the "15 minute wedge." Light rail users are expected to re-explore the roadway option to the point at which the value of non-time generalized cost factors just equals the value of the travel time advantage offered by road. If non-time costs are moderate to high, travel time convergence will occur at a non-zero time differential between road and rail. Such is the case at-hand.

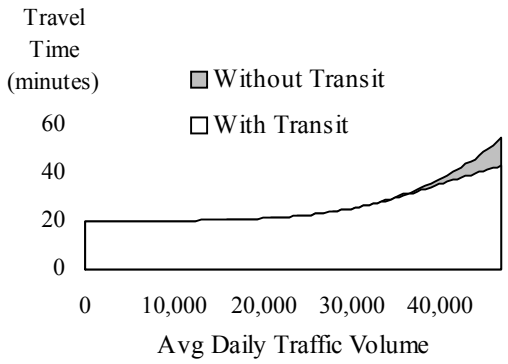


Figure A 4.1 Illustration of the "With" and "Without Transit" curves for the Butterfield-Sacramento Corridor

Introduction

This report presents the results for the Butterfield-Sacramento corridor case study as part of Streamlined Strategic Corridor Travel Time Management study. The purpose of the study is to use the convergence measurement technique to derive a repeatable performance measurement for rail transit in congested corridors. This case study measures the performance of Sacramento's light rail system using the methodology developed in Subtask 1c. The methodology consists of calibrating the Mogridge-Lewis Convergence Hypothesis (MLC) model with survey data and using the model to quantify delay savings attributable to transit at different roadway traffic volumes. The savings are estimated for three different user categories using highway traffic data and light rail ridership in the corridor.

Study Methodology

The study methodology consists of four main steps:

1. Collecting highway travel data (traffic volume, distance, travel time, and vehicle occupancy in the corridor); and light rail ridership data along the corridor;
2. Conducting door-to-door travel time surveys and deriving the inter-modal convergence;
3. Estimating the "with transit" and "without transit" model and related curves and estimating the hours of delay saved due to transit; and
4. Quantifying delay savings by user category, namely, (i) light rail riders ("market" benefits); (ii) common segment users ("club" benefits); and, (iii) parallel highway users ("spillover" benefits).

During the first step, HLB collected HPMS data, local arterials traffic data, and light rail ridership data from Sacramento Area Council of Governments (the local MPO) and Sacramento Regional Transit (the local transit authority). The data were used to estimate the model parameters.

For the second step, data was collected on site by a survey team. A corridor, as defined in this study, is a principal transportation artery into the central business district. Multiple transportation services are available to commuters who use this artery. Additionally, during the peak period a large number of commuters utilize this route in their door-to-door commute.

A statistical sample of trips was generated in the corridor by identifying random trip end point in the zones at either end of the corridor and joining them so that trips alternated between zones. These zones are catchment zones where travelers converge or diverge from either the transit station or the principal highway route. In this study these zones are defined as the access segment and the component of the corridor common to all trips for a given mode, regardless of trip end location, is defined as the common segment.

Survey crews were instructed to follow specific routes that consisted of an access segment—dependent on the catchment zone considered for the trip—and a common segment. The data collected include start times and arrival times for each segment, by mode, congestion level, seating availability, weather, road conditions, and travel costs for each segment.

Data were collected over a period of three consecutive days (Tuesday to Thursday) during the first week of May 1999. The days of the week were sampled to eliminate fluctuations in traffic patterns and volumes due to the day of week effects. Trips were validated to minimize the effects of unusual or circumstantial conditions. Sixty valid trips were selected to ensure a statistically adequate sample size. The study employed the maps and routes connecting several zones within a residential area to several points within Sacramento's central business district.

Step three consisted of estimating the "with transit" curve based on the traffic volume and the door to door travel time. Using the model developed in Subtask 1c, HLB derived the "without transit" curve and estimated the hours of delay saved due to transit. This performance metric is defined as the vertical difference between the two curves.

In step four, the hours of delay saved due to transit are aggregated into three user categories. Savings by common highway-segment users are estimated using the traffic volume on the segment. Savings by light rail riders are estimated using the ridership data for each station along the corridor. Savings by parallel highway users are estimated using traffic volume on parallel highways and arterials within the corridor. The magnitude of the savings decreases as the distance between the common segment and the arterial increases.

Plan of the Report

This report presents the results from the Butterfield-Sacramento corridor case study. Following this introduction, Chapter 2 presents an overview of the model and methodology to estimate the delay saving. Chapter 3 displays the corridor characteristics and a description of the principal modes of transportation within the corridor. Chapter 4 presents the results from the 1999 door-to-door travel survey and shows the model estimation results. The chapter estimates the hours of delay saved due to transit per person per day, and provides a monetary value of the delay saved for three user categories. Appendices provide maps of the residential area and the central business district as well as supporting data and supplementary results on the survey findings by route.

Methodology and Model Overview

The methodology consists of four steps:

1. Estimating the Corridor Performance Baseline
2. Estimating the Corridor Performance in the Absence of transit
3. Extrapolating Delay Savings Due to Transit
4. Estimation of Corridor Performance without Re-calibration

Estimating the Corridor Performance Baseline

The Model This model establishes a functional relationship between the person trip volume –all modes—and the average door to door travel time by auto in the corridor.

The door to door travel time by auto can be determined using a logistic function which calculates the door to door travel time in terms of travel time at free flow speed, trip time by high capacity rail mode, and the volume of trips in the corridor for all modes. The door to door travel time can be estimated as follows:

$$T = (T_c - T_{ff}) / (1 + e^{-(\delta + \varepsilon V1)}) + T_{ff} \quad (1)$$

Where T_{a1} is auto trip time,

Tc is trip time by high-capacity rail mode

T_{ff} is auto trip time at free-flow speed,

V is person trip volume in the corridor by auto, and

δ, ε are model parameters

Equation 1 implies that the door to door auto trip time is equal to the trip time at free-flow speed plus a delay which depends on transit travel time and the person trip volume in the corridor.

In other words, when the highway volume is close to zero, travel time is equal to travel time at free flow speed.($T = T_{ff}$). As the volume increases, the travel time is equal to T_{ff} plus a delay due to the high volume, but adjusted to the travel time by high capacity transit. That is the high capacity transit alleviates some of the highway trip delay as some trips shift to transit.

Equation 1 is transformed into a linear functional form before the parameters δ and ε can be estimated, the transformed equation will be:

$$U = \delta + \varepsilon V_1 \quad (2)$$

Where $U = \ln [(T_c - T_{ff}) / (T - T_{ff}) - 1]$

Equation 2 is estimated using Ordinary Least Squares regression.

Data The data required for the estimation of the above equations are:

- person trip volume on the highway which can be calculated by dividing the traffic volume by the average vehicle occupancy (auto and buses). This data are available through HPMS data base and MPO's traffic data.
- free flow trip time is a constant.
- high capacity trip time is a constant.

The parameters δ and ε do not have to be re-estimated each year, they are both specific to the corridor and are relatively stable over the years. So periodically, the person trips volume can be inserted into Equation 1 to estimate the door to door travel time by auto.

Estimating the Corridor Performance in the Absence of transit

The Model This model represents the concept to quantify the role of transit in congestion management. In the absence of transit, the travel time Ta is estimated as:

$$T_a = T_{ff} * (1 + A (V^*)^{\beta}) \quad (3)$$

Where T_a is the door to door travel time in the absence of transit,

T_{ff} is the trip travel time at free-flow speed,

V* is the volume of person trips by auto in the absence of transit,

A is a scalar, and β is a parameter.

Equation 3 implies that the door to door travel time in the absence of transit depends on the travel time at free-flow speed and the level of congestion on the road in the absence of transit.

The volume of person trips by auto in the absence of transit, however, depends on several factors:

- The existing auto and bus person trips on the highway.
- The percentage of person transit trips shifting to auto
- The percentage of person transit trips shifting to bus
- The number of additional cars in the highway
- The number of additional buses in the highway
- The occupancy per vehicle in the absence of transit The volume of person trips by auto, in the absence of transit, can then be estimated as:

$$\mathbf{V^* = V_1 + \alpha_1 V_c + \alpha_2 V_b} \qquad \mathbf{(4)}$$

Where V_1 is the existing auto volume,

V_c is the transit person trips diverted to cars,

V_b is the transit person trips diverted to buses, and

α_1, α_2 are the coefficients that incorporate the passenger car equivalent factor, and the occupancy per vehicle (cars and buses).

The trips diverted to cars and buses depend mainly on the degree of convergence in the corridor. This degree of convergence reflects the transit user behavior and the composition of these users. The transit users can be divided into 3 categories:

Type 1: "Explorers" who are casual switchers and who will divert to Single Occupancy Vehicles in the absence of transit.

Type 2: Commuters with low elasticity of demand with respect to generalized cost and who will divert to use the bus or carpool.

Type 3: Commuters with high elasticity of demand with respect to generalized cost and who will forgoes the trip.

The higher the degree of convergence (auto and rail door to door travel times are very close), the higher the shift of transit riders to cars and buses. Therefore, higher degree of convergence will lead to higher delay, which translates into higher savings due to transit.

In words, Equation 3 shows that in the absence of transit and in the case of a high degree of convergence, the person trip volume is very high which translates into a high trip time (excessive delay). The relationship between trip time and person trip volume can be expressed as a convex curve (as the volume increases, travel time increases at an increasing rate). The figure below illustrates the relationship between the volume and travel time both in the presence and in the absence of transit.

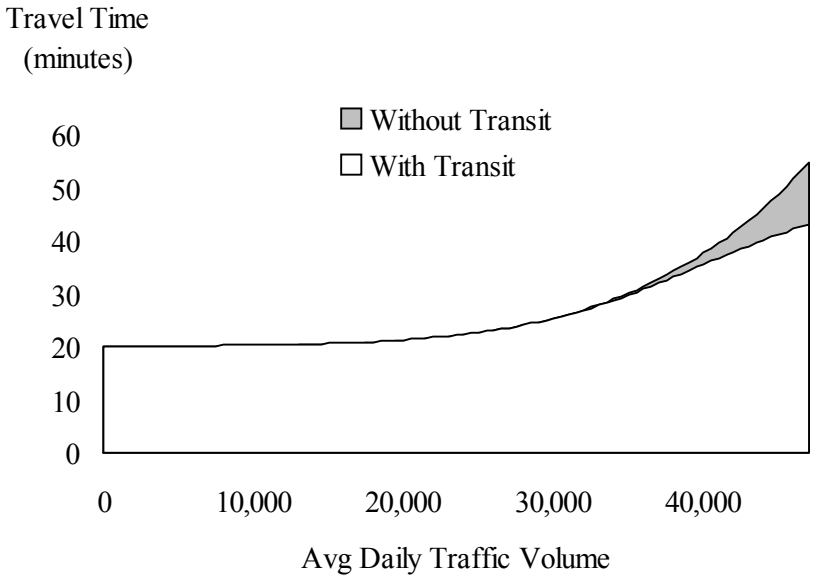


Figure A 4.1 Corridor Travel Times With and Without Transit

Data The data required to populate this model consist of:

- Highway person trip volume (used in the previous model)
- Transit ridership data
- Fleet composition (cars and buses percentages out of the total traffic)
- Cars and buses vehicle occupancy
- Passenger car equivalent factor
- Degree of convergence to determine the percentage person trips shifting to cars and buses
- Free-flow travel time which is a constant

Equation 3 is specific to the corridor and do not need to be estimated each year. It will only be necessary to re-estimate them with an updated degree of convergence if a major change is made to the transit level of service or the highway structure.

Extrapolating Delay Savings Due to Transit

While the MLC hypothesis proves to be valid during the peak period only, the delay savings due to transit can be estimated during off-peak as well. This metric can be estimated as the vertical difference between the "without transit" curve and the "with transit" curve. That is at a specific person trip volume, the difference in travel times between the two cases can be defined as "the hours of delay saved due to transit".

The estimated hours of delay savings due to transit are an aggregation of three different user savings: savings by Metro riders (market benefits), savings by highway users (club benefits), and savings by users of parallel highways (spillover benefits).

The market benefits are estimated based on delay saved (which depends on the distance traveled) for each rider within the common segment.

The club benefits are estimated based on the volume on the common segment using origin-destination table and the daily trip distribution.

The spillover benefits are estimated based on the savings per mile, traffic volume, and the distance traveled on segments parallel to the common segment. The spillover benefits are calculated by multiplying the traffic volume with a percentage of the delay savings. This percentage decreases as the distance between the common segment and the parallel highway increases.

Estimation of Corridor Performance without Re-calibration

The framework, presented above, provides an MLC-based approach to making repeated measures of transit-induced savings in corridor delay without the need for repeated MLC surveys. The approach rests on the theoretical proposition, that a stable and measurable relationship exists between roadway traffic growth over time and the inter-modal (highway-transit) equilibrium dynamics that give rise to delay savings in a congested corridor. In the absence of major changes in the level of highway supply or transit service in the corridor, this measured relationship, or model, provides a formula-based performance measurement system in lieu of a survey-based approach. In addition to the obvious cost advantages, this approach provides FTA with (i) an efficient means of measuring and comparing transit performance in strategic corridors; and (ii) a consistent performance assessment tool for transfer to MPOs throughout the country.

Corridor Overview

The Butterfield-Sacramento corridor is about 11.6 miles in length and connects the residential area around Bradshaw Road and the central business district, downtown Sacramento. The residential catchment zone is centered around Butterfield Metro Station. Trip end points within the residential zone are no more than a 15-minute drive to the station. The downtown Sacramento CBD zone, centered around 9th and K street light rail station, extends for a radius of .5 miles. App. Annex A1 provides maps of the residential and business district zones considered in this study. The Butterfield-Sacramento light rail line is part of the 12-mile line connecting Downtown and Butterfield, east of Sacramento.

Principal Travel Modes

The "principal travel mode" is defined as the mode used during the common segment of each individual trip. The main transportation modes serving the Butterfield-Sacramento Corridor are automobile and the light rail. Automobile routes can be broken into three distinct sections:

1. The route between the residential point and the intersection of US-50 and Bradshaw Road (Access1);
2. The route from the intersection of US-50 and Bradshaw Road to the US-50/ I-5 Bypass (Common Segment); and
3. The route from the intersection of US-50/I-5 Bypass to the CBD destination point (Access 2).

For a morning rush hour trip, survey drivers followed Access 1 to the common segment. The common segment route originated at the intersection of US-50 and Bradshaw Road in Butterfield Station area. Drivers followed US-50 to I-5 Bypass. From the end of the common segment, survey drivers followed Access 2 to the downtown points, at which time they parked at the closest parking lot and proceeded on foot to the end point. The evening rush hour trip covered the same progression in the opposite direction.

The routes for the light rail mode riders can be broken into three distinct sections:

1. The route between the residential point and the Butterfield Station (Access1);
2. The route between the Butterfield Station and the 9th and K Street Station (Common Segment); and
3. The route between the 9th and K Street Station and the CBD point (Access2).

For a morning rush hour trip, survey crews drove Access 1 to the Butterfield Station parking lot and walked from the lot to the MAX station. The route taken for the common segment consisted of a light rail trip which began at the Butterfield Station and continued to the 9th and K Street Station. From the end of the common segment, the surveyor walked Access2 to the downtown points. The evening rush hour trip covered the same progression in the opposite direction. On average, trains run every 10 minutes during peak hours. Table A 4.2 displays some of the principal performance and service characteristics of the corridor.

Table A 4.2 Performance and Service Characteristics for Butterfield-Sacramento Corridor

	Automobile	Light Rail
Number of stops	N/A	16
Number of Streets and Highways	1	N/A
Tolls/Fares for a one way (in dollars)	$0.00	$1.25

Figure A 4.2 Map of the Butterfield-Sacramento Corridor

Principal findings

This chapter starts by presenting the results from the door-to-door travel survey conducted during the first week of May 1999. The travel survey data are used to derive the inter-modal convergence level in the Butterfield-Sacramento corridor. The chapter then presents the estimation of the hours of delay saved due to transit for different user categories.

The Convergence Level

The starting point to estimate the "without transit" curve is to determine the convergence level based on the key findings from the 1999 door to door travel data.

The door to door travel survey for the Butterfield-Sacramento Corridor found that:

- Average door-to-door travel times for auto and metro rail, are not similar, 46.0 minutes by light rail versus 30.8 minutes by auto (Table A 4.2).
- Travel time reliability, as represented by the standard deviation of average travel time, is similar, 3.4 for light rail mode compared and 2.8 for the auto mode (Table A 4.3).
- Commuters experienced similar travel times in the morning and in the evening reflecting the similar traffic dynamics of the inbound peak flow versus the outbound peak flow in the corridor (Table A 4.4).
- Statistical analysis shows that the mean trip time by auto was at most 17 minutes longer with 95% confidence (Table A 4.5).
- The common segment travel time was greater for the light rail mode than for the transit mode, 28.4 minutes versus 13.1 minutes. The difference of 15.3 minutes between the two modes is due to the several stops of the light rail (16 stops) while the common segment for auto consisted of one highway (Table A 4.3).
- Access segment travel times was similar between auto commuters and transit commuters (Table A 4.3).

Table A 4.3 Results for the Butterfield-Sacramento Corridor

	Automobile	Light Rail
	Total Travel Time	
Mean	30.8	46.0
Standard Deviation	2.8	3.4
	Access Segment Travel Time	
Mean	17.7	17.6
Standard Deviation	2.6	1.5
	Common Segment Travel Time	
Mean	13.1	28.4
Standard Deviation	1.5	1.5
Sample Size	30	30

Table A 4.4 Comparison of AM and PM Trip Times by Modes

	Auto	Metro Rail
Inbound AM Average Trip Time	30.5	47.0
Outbound PM Average Trip Time	31.1	45.1

Table A 4.5 Statistical Testing of Convergence Hypothesis

Difference in Mean Travel Times by Mode (Auto- Metro Rail minutes)		15.2
Standard Error of the Difference of the Means (minutes)		0.80
Hypothesis: "The difference between the mean travel times by modes is at most..."	Significant at the 0.10 Level (90% Confidence)	Significant at the 0.05 Level (95% Confidence)
14 Minutes	NO	NO
15 Minutes	NO	NO
16 Minutes	NO	NO
17 Minutes	YES	YES
18 Minutes	YES	YES

The results in Table A 4.5 indicate that light rail in the defined corridor has drawn door-to-door travel times by highway and light rail to within 16 minutes of one another during congested roadway conditions (with 95 percent statistical confidence).

Although an inter-modal travel time convergence of 16 minutes is sufficient to yield delay savings to highway users (as compared to the "without rail" case – see below), full convergence would of course yield even greater savings. Why is the convergence level as high as 16 minutes? Stated differently, why is it that, even though door-to-door average peak-period roadway travel time is 16 minutes less than the average door-to-door travel time by light rail, light rail users are not re-exploring the roadway option by enough to "bid-up" roadway times any further?

The Mogridge-Lewis framework predicts that non-time related roadway travel costs (i.e, the non-time elements of "generalized cost" such as parking costs, fuel costs and so on) account for the "16 minute wedge." Light rail users are expected to re-explore the roadway option to the point at which the value of non-time generalized cost factors just equals the value of the travel time advantage offered by road. If non-time costs are moderate to high, travel time convergence will occur at a non-zero time differential between road and rail

Methodology Application on Butterfield-Sacramento Corridor

Data HLB obtained traffic volume data (HPMS data) from the regional MPO Sacramento Area Council of Governments. The ridership data were obtained from the Sacramento Regional Transit. In addition, door to door travel time survey was conducted to derive the degree of convergence in the corridor.

Model The traffic volume and travel time data were used to populate the model, Equation 1 is estimated as follows:

$$T_{a1} = (50 - 20) / (1 + e^{-(-6.817 + 0.00016\,(V))}) + 20 \quad (1)$$

When V is equal to 0, the travel time is equal the travel time at free flow speed (20 minutes). For an auto traffic volume of 40,000 between Bradshaw Road and Downtown Sacramento (based on SACOG 1998 O-D tables), the travel time is equal to 28.05 minutes.

Similarly, Equation 2 is estimated based on auto travel volume, transit ridership data, and convergence level estimate from the survey.

$$T_{a2} = 50 * (1 + 1.22E\text{-}21\ (V^*)^{4.5}) \quad (2)$$

The auto traffic volume in the absence of transit is determined by adding the auto volume in the presence of transit to the generated auto trips by transit riders. The generated is based on:

- About 40% of person transit trips will be forgone (determined by the corridor convergence level).
- The average vehicle occupancy (HOV and non-HOV) is 1.2 for cars and 40 for buses.
- Car trips will make about 90% of trips.

Benefit Estimation

To estimate the travel time saving (TTS) attributed to transit, the current traffic volume is inserted into Equation 1 and 2. An auto volume of 37,500 results into:

$$T_{a1} = 33.72,\ T_{a2} = 34.97, \text{ and . } TTS = T_{a2} - T_{a1} = 1.25$$

That is on average, on Butterfield-Sacramento corridor, transit saves about 1.25 minutes per auto trip (6.5 seconds per mile) during the peak period.

Once the average travel time saving per vehicle is estimated, the savings are weighted to reflect the congestion level at each time of the day. The Avg Traffic Volume by time of the day is shown below:

Feeding the volume levels for 1999, for the Butterfield-Sacramento corridor into equation (1) and (2), HLB estimated the hours of delay saved due to transit for 1999. The estimated hours of delay savings due to transit are an aggregation of three different user savings: savings by Metro riders (market benefits), savings by US-50 common segment users (club benefits), and savings by users of parallel highways (spillover benefits).

The market benefits are estimated based on delay saved (which depends on the distance traveled) by each rail rider within the common segment (Table A 4.6). The club benefits are estimated based on the volume on the common segment using origin-destination table and the daily trip distribution (Table A 4.7). The spillover benefits are estimated based on the savings per mile, traffic volume, and the distance traveled on segments parallel to the common segment (Table A 4.8). The magnitude of savings by the commuters on these highways decreases with the distance to the common segment.

Table A 4.6 Market Benefits for Butterfield-Sacramento Corridor

Station	In-bound Trips	Out-bound Trips	Daily Savings (hours)
Butterfield	2393	-	32.41
Tiber	142	42	2.37
Starfire	270	137	4.96
Watt/Manlove	913	205	12.87
College Greens	431	228	7.14
Power Inn	575	116	7.02
65th St.	973	807	16.87
59th St	221	123	3.03
48th St	153	55	1.69
39th St	191	147	2.52
29th Street	1428	809	18.18
23rd St	520	464	8.66
16th St	401	364	7.25
13th St	112	188	3.05
Archives Pl	314	494	8.75
8th & O	543	803	15.49
7th & Capitol	440	460	10.97
Total	8,723	3,685	128

Table A 4.7 Club Benefits for Butterfield-Sacramento Corridor

	Distance (miles)	Avg Traffic Volume	Daily Savings (hours)
Common Segment (US 50)	9.6	85,750	1,153.19
Access Segment (average)	2	41,500	116.27
Total	11.60		1,269.46

Table A 4.9 shows the summary of benefits by category. The results indicate that the delay saving due to transit is about 1.25 minutes per trip one way (about 6 seconds per mile). Using a travel time value of $15 per hour and an average of 250 working days per year, the yearly delay saving can be valued at $7 million in 1999, this can be translated into a $ 0.6 million per rail mile in the Butterfield-Sacramento Corridor. The summary table shows that 67% of the savings are club savings while only 7% are market savings. These results illustrate the relative low ridership and the high use of automobile in the corridor.

Table A 4.8 Spillover Benefits for Butterfield-Sacramento Corridor

Highways in the corridor	Distance (miles)	Avg Traffic Volume	Daily Savings (hours)
Folsom Street	10	11,237	125.93
Fair Oaks	7	6,997	65.18
Hurley Way	7	6,158	56.16
Arden Way	6	8,053	61.60
Keifer Blvd.	5	9,934	59.14
Broadway	4	8,205	36.78
S Street	4	5,156	21.67
U Street	4	5,156	20.22
V Street	4	5,156	20.22
M Street	3	5,156	16.25
Total			483.16

Table A 4.9 Benefits Summary

	Daily Savings		Yearly Savings
Benefit Category	In Hours	In Dollars	In Dollars
Market	128	$ 1,920	$ 480,007
Club	1,269	$ 19,042	$ 4,760,480
Spillover	483	$ 7,247	$ 1,811,851
Total	1,881	$ 28,209	$ 7,052,338

The methodology implies that in the absence of major infrastructure improvements or strong growth in volume of traffic the performance metric will remain stable. So, it should suffice to gather corridor travel time—degree of convergence—once every several years. In the case of major infrastructure improvement or a change in the transit service, however, door to door travel time data should be collected to estimate an accurate performance metric.

Annex A 4.1 Views of the Sacramento Butterfield Light Rail Corridor

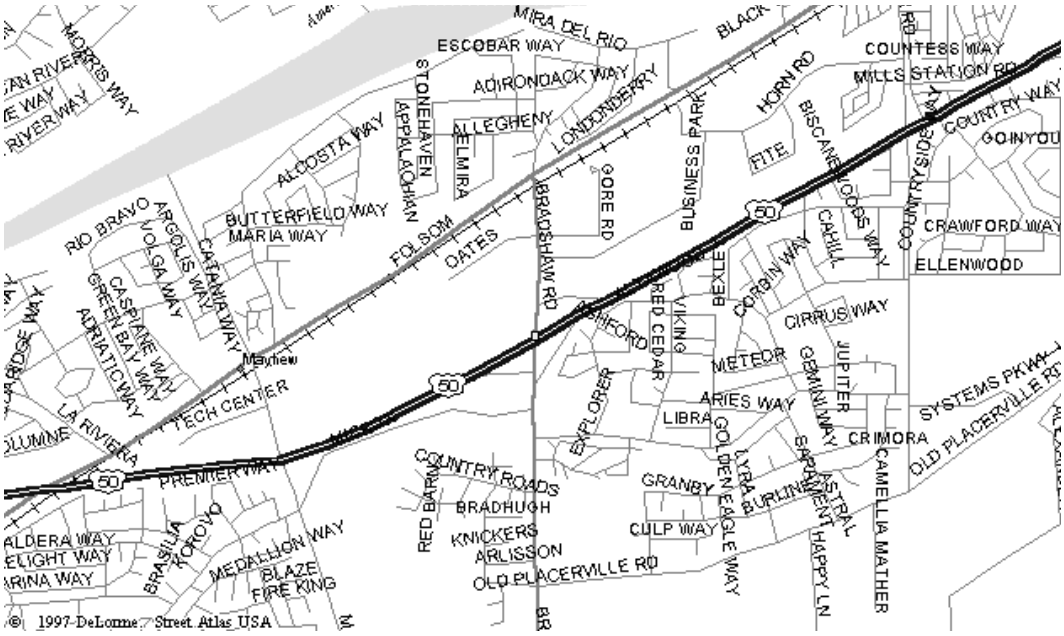


Figure A 4.3 Map of the residential district

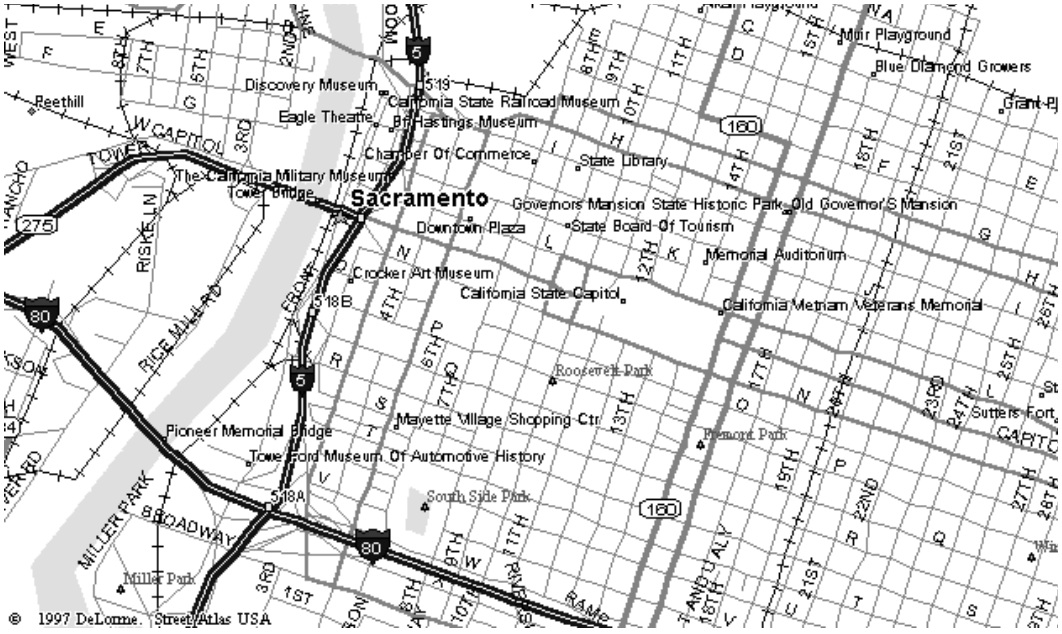
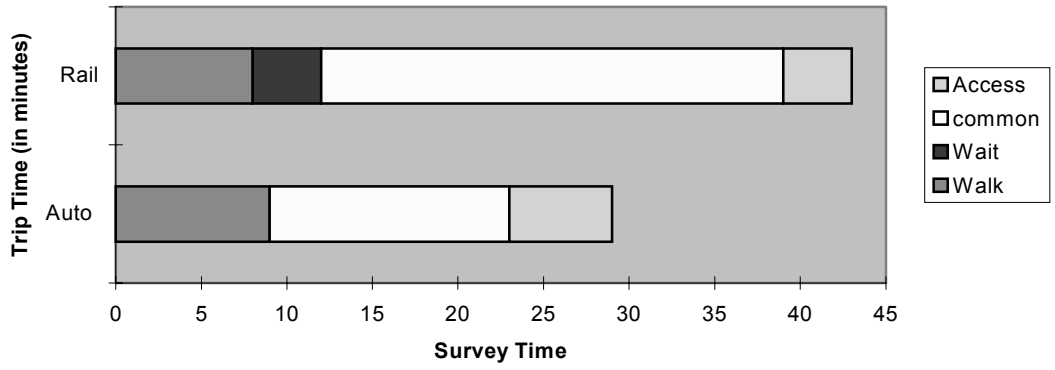


Figure A 4.4 Map of the central business district

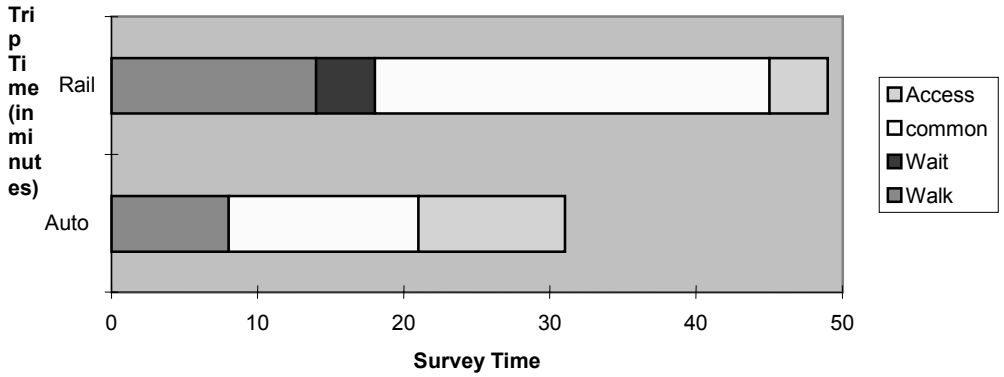
Annex A 4.2 The survey findings by route

CORRIDOR: Butterfield - Sacramento SUMMARY TABLE FOR ROUTE A1: Old Placerville & Happy Ln - 3rd & K		
	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	43
In Common Segment	14	27
Outside Common Segment	6	4
Wait Time	0	4
Walk Time	9	8
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	20.9
In Common Segment	41.1	26.7
Outside Common Segment	20.0	45.0



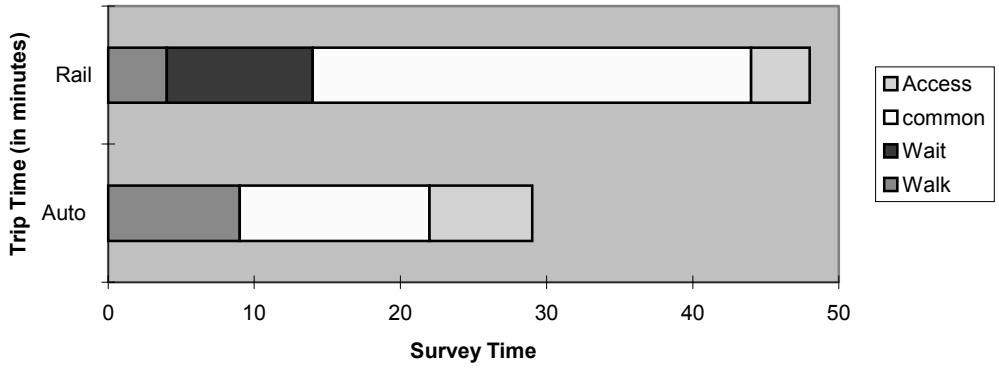
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE B2:
Old Placerville & Routier Rd - 3rd & L

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	31	49
In Common Segment	13	27
Outside Common Segment	10	4
Wait Time	0	4
Walk Time	8	14
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	22.5	18.4
In Common Segment	44.3	26.7
Outside Common Segment	12.0	45.0



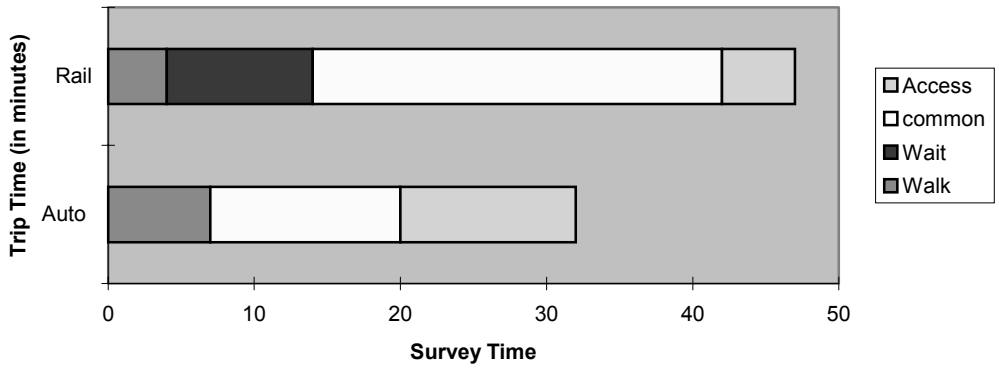
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE C3:
Mira del Rio & Escobar Way - 5th & L

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	48
In Common Segment	13	30
Outside Common Segment	7	4
Wait Time	0	10
Walk Time	9	4
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	18.8
In Common Segment	44.3	24.0
Outside Common Segment	17.1	45.0



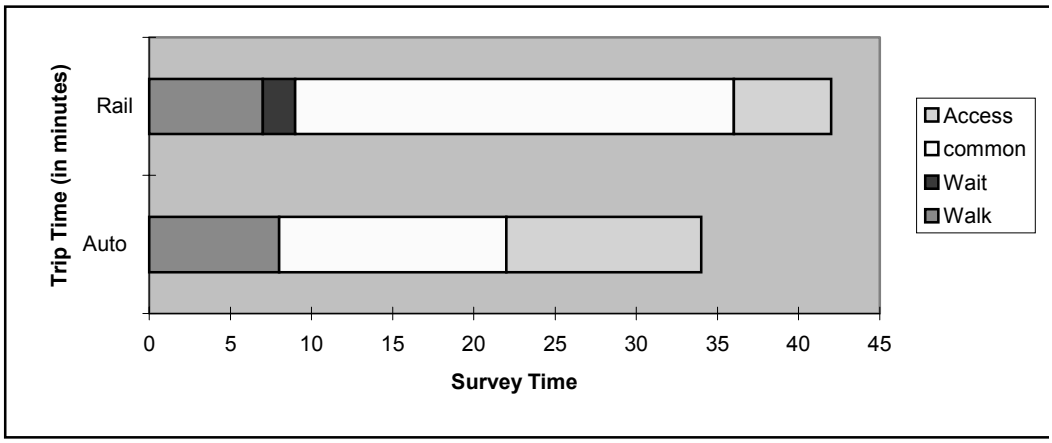
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE D4:
Bradshaw & Mira del Rio - 3rd & Capital

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	32	47
In Common Segment	13	28
Outside Common Segment	12	5
Wait Time	0	10
Walk Time	7	4
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	21.8	19.1
In Common Segment	44.3	25.7
Outside Common Segment	10.0	36.0



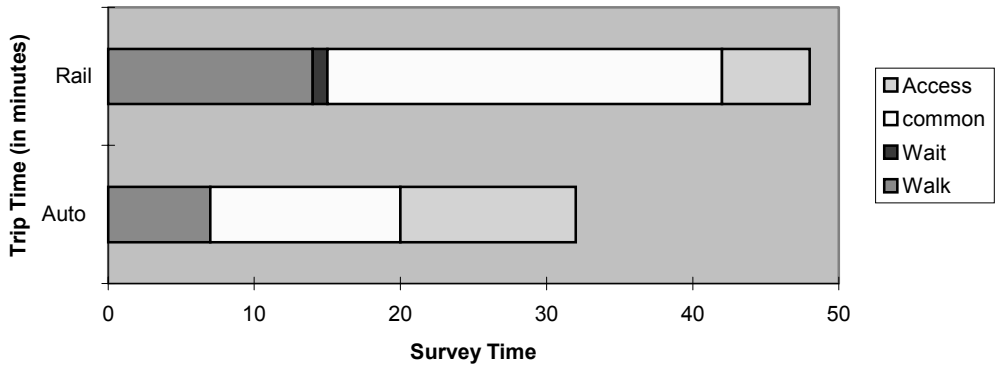
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE E5:
Bradshaw & Old Placerville - 4th & J

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	34	42
In Common Segment	14	27
Outside Common Segment	12	6
Wait Time	0	2
Walk Time	8	7
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	20.5	21.4
In Common Segment	41.1	26.7
Outside Common Segment	10.0	30.0



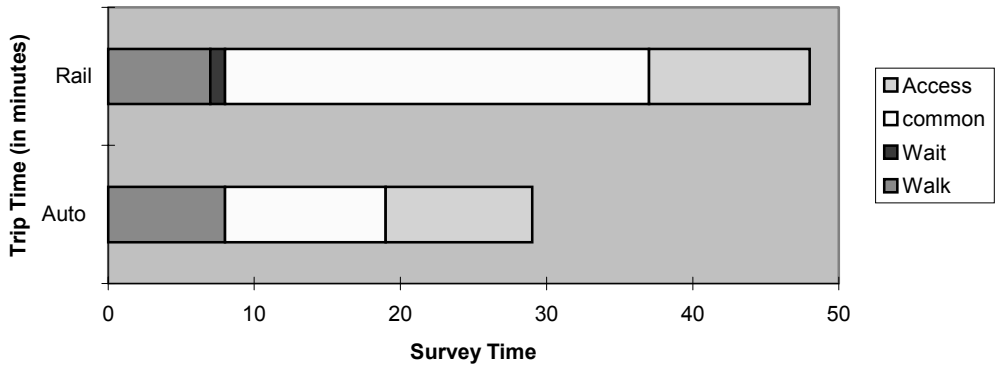
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 1A:
3rd & K - Old Placerville & Happy Ln

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	32	48
In Common Segment	13	27
Outside Common Segment	12	6
Wait Time	0	1
Walk Time	7	14
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	21.8	18.8
In Common Segment	44.3	26.7
Outside Common Segment	10.0	30.0



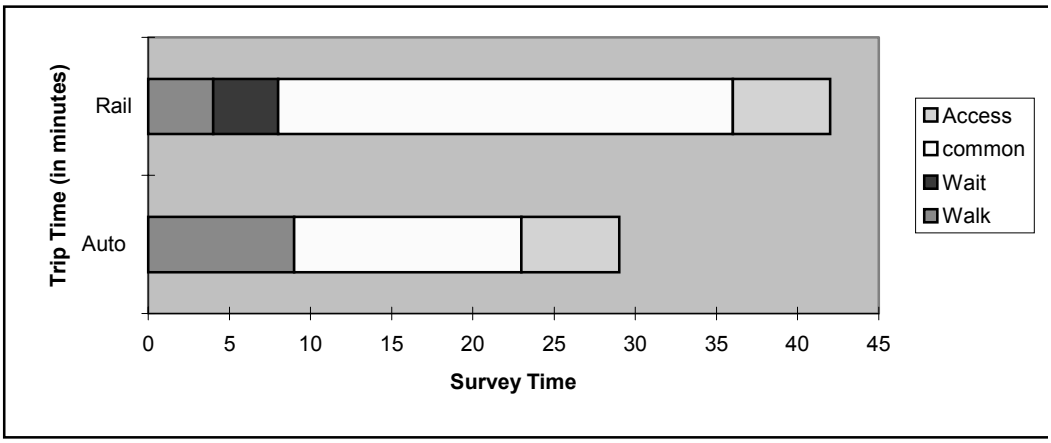
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 2B:
3rd & L - Old Placerville & Routier Rd.

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	48
In Common Segment	11	29
Outside Common Segment	10	11
Wait Time	0	1
Walk Time	8	7
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	18.8
In Common Segment	52.4	24.8
Outside Common Segment	12.0	16.4



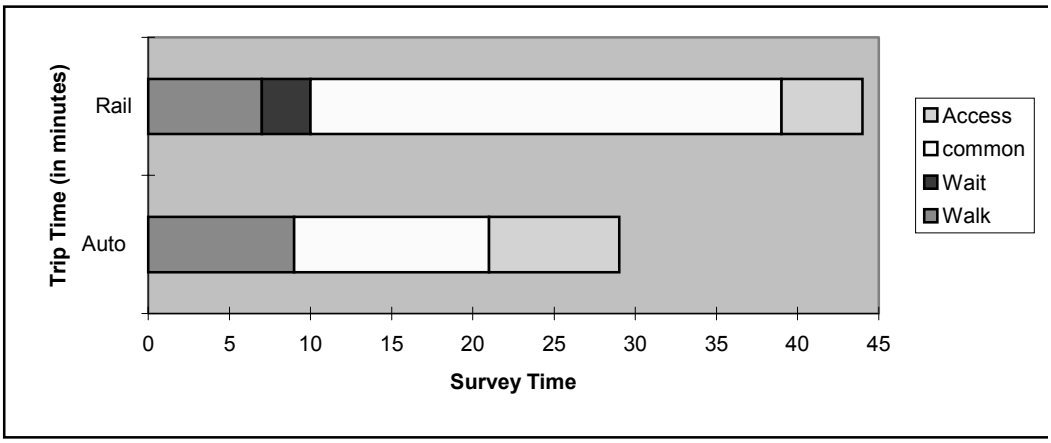
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 3C:
5th & L - Mira del Rio & Escobar

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	42
In Common Segment	14	28
Outside Common Segment	6	6
Wait Time	0	4
Walk Time	9	4
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	21.4
In Common Segment	41.1	25.7
Outside Common Segment	20.0	30.0



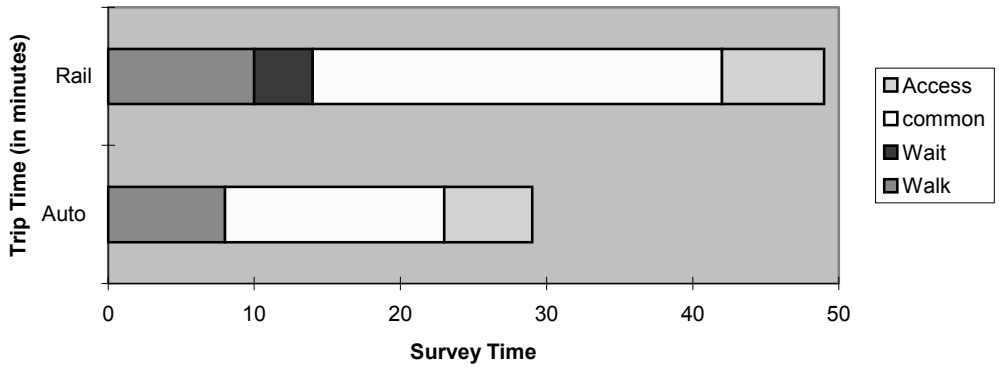
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 4D:
3rd & Capital - Bradshaw & Mira del Rio

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	44
In Common Segment	12	29
Outside Common Segment	8	5
Wait Time	0	3
Walk Time	9	7
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	20.5
In Common Segment	48.0	24.8
Outside Common Segment	15.0	36.0



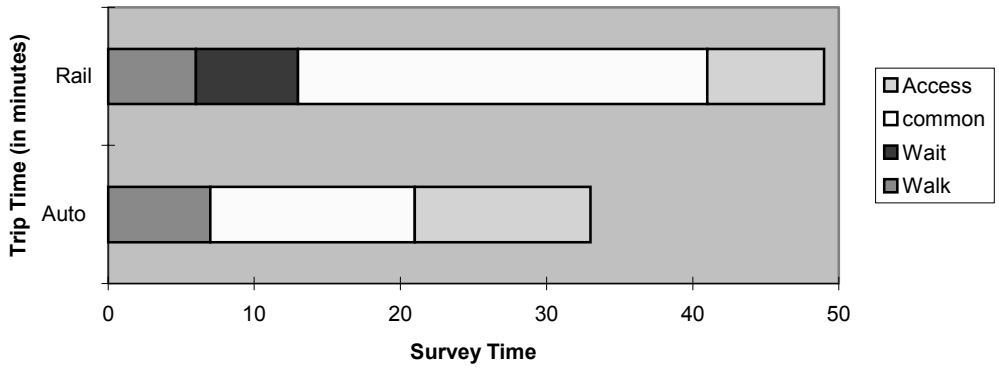
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 5E:
4th & J - Bradshaw & Old Placerville

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	49
In Common Segment	15	28
Outside Common Segment	6	7
Wait Time	0	4
Walk Time	8	10
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	18.4
In Common Segment	38.4	25.7
Outside Common Segment	20.0	25.7



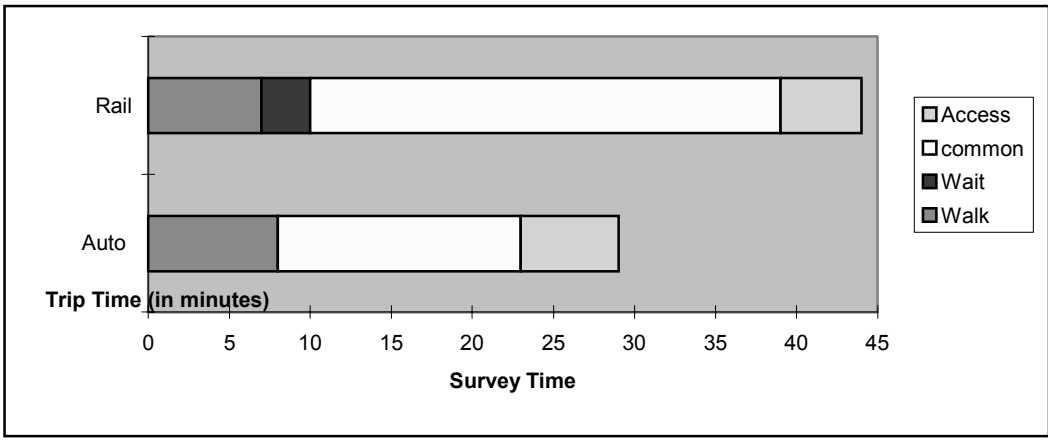
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE B1:
Old Placerville & Routier Rd - 3rd & K

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	33	49
In Common Segment	14	28
Outside Common Segment	12	8
Wait Time	0	7
Walk Time	7	6
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	21.1	18.4
In Common Segment	41.1	25.7
Outside Common Segment	10.0	22.5



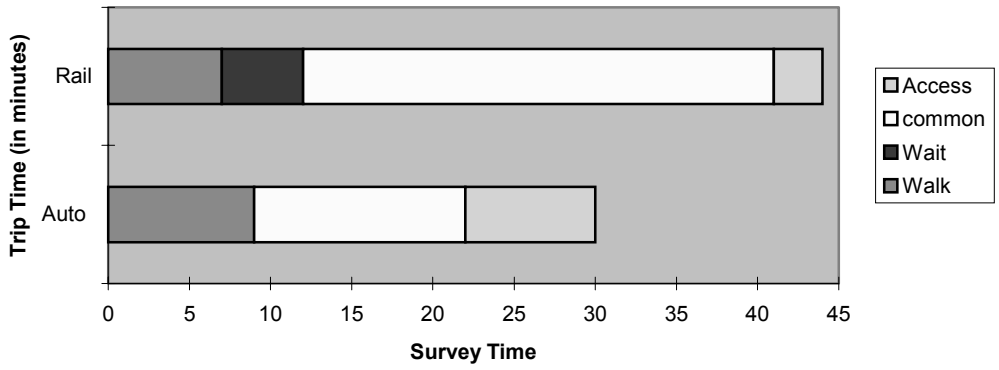
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE
ROUTE C2
Mira del Rio & Escobar Way - 3rd & L

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	44
In Common Segment	15	29
Outside Common Segment	6	5
Wait Time	0	3
Walk Time	8	7
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	20.5
In Common Segment	38.4	24.8
Outside Common Segment	20.0	36.0



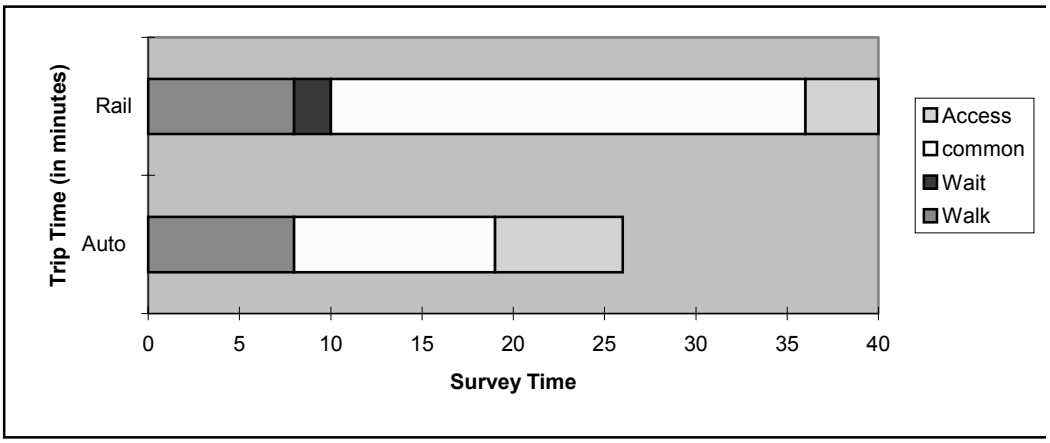
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE D3:
Bradshaw & Mira del Rio - 5th & L

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	30	44
In Common Segment	13	29
Outside Common Segment	8	3
Wait Time	0	5
Walk Time	9	7
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	23.2	20.5
In Common Segment	44.3	24.8
Outside Common Segment	15.0	60.0



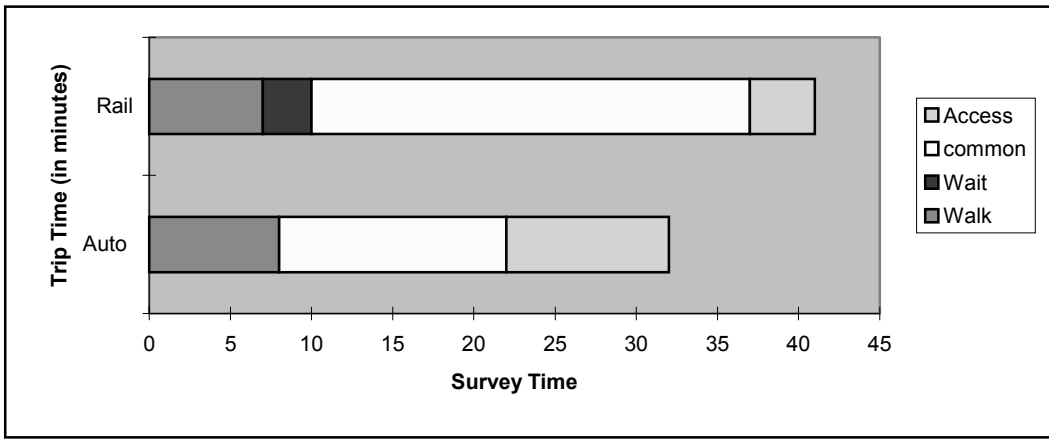
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE E4:
Bradshaw & Old Placerville - 3rd & Capital

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	26	40
In Common Segment	11	26
Outside Common Segment	7	4
Wait Time	0	2
Walk Time	8	8
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	26.8	22.5
In Common Segment	52.4	27.7
Outside Common Segment	17.1	45.0



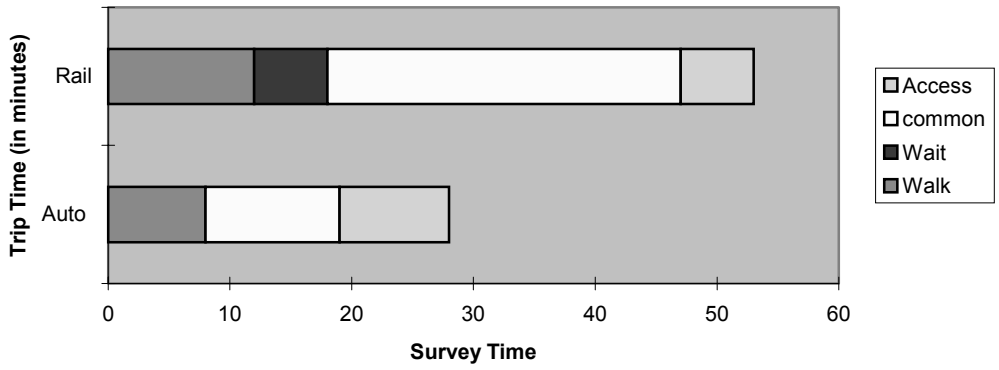
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE F5:
Mayhew & Keifer - 4th & J

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	32	41
In Common Segment	14	27
Outside Common Segment	10	4
Wait Time	0	3
Walk Time	8	7
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	21.8	22.0
In Common Segment	41.1	26.7
Outside Common Segment	12.0	45.0



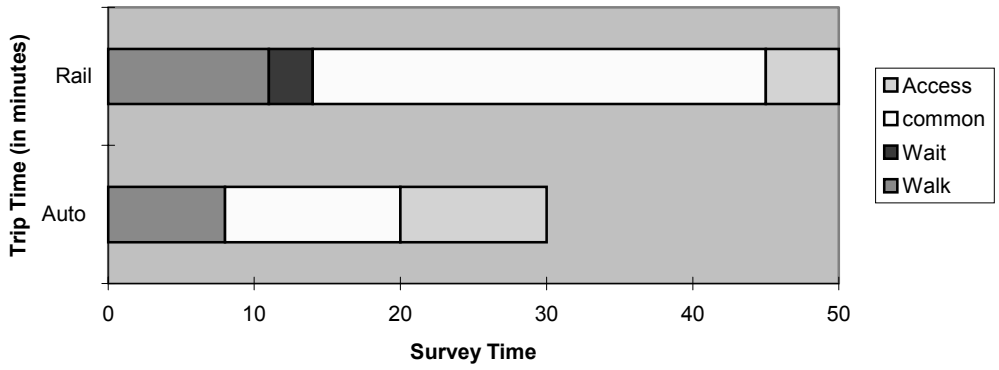
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 1B:
3rd & K - Routier & Old Placerville

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	28	53
In Common Segment	11	29
Outside Common Segment	9	6
Wait Time	0	6
Walk Time	8	12
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.9	17.0
In Common Segment	52.4	24.8
Outside Common Segment	13.3	30.0



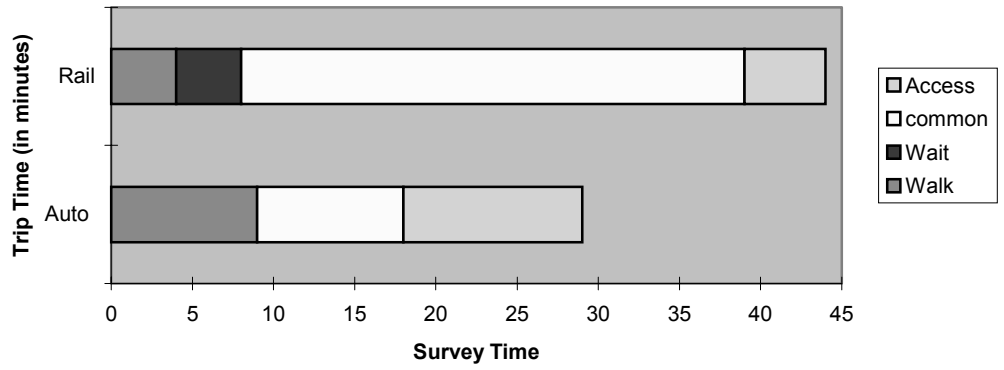
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 2C:
3rd & L - Mira del Rio & Escobar Way

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	30	50
In Common Segment	12	31
Outside Common Segment	10	5
Wait Time	0	3
Walk Time	8	11
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	23.2	18.0
In Common Segment	48.0	23.2
Outside Common Segment	12.0	36.0



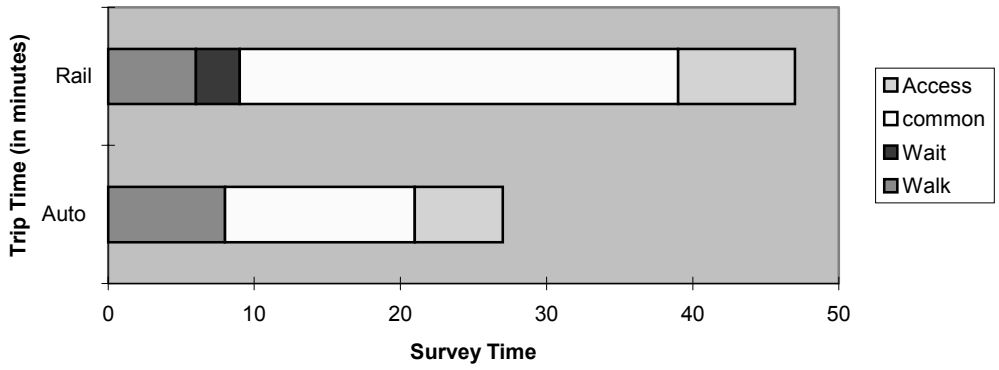
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 3D:
5th & L - Bradshaw & Mira del Rio

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	44
In Common Segment	9	31
Outside Common Segment	11	5
Wait Time	0	4
Walk Time	9	4
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	20.5
In Common Segment	64.0	23.2
Outside Common Segment	10.9	36.0



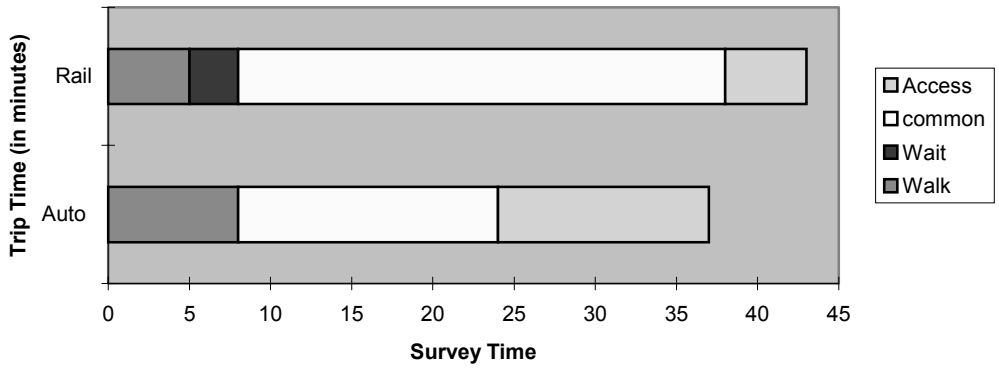
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 4E:
3rd & Capital - Bradshaw & Old Placerville

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	27	47
In Common Segment	13	30
Outside Common Segment	6	8
Wait Time	0	3
Walk Time	8	6
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	25.8	19.1
In Common Segment	44.3	24.0
Outside Common Segment	20.0	22.5



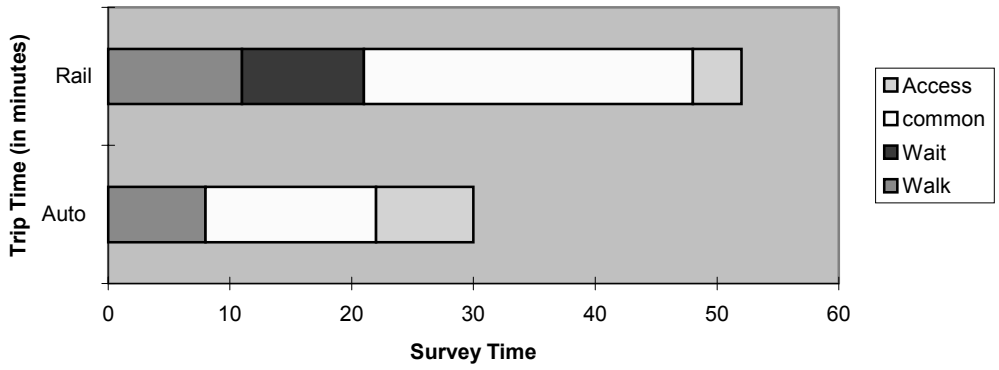
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 5F:
4th & J - Mayhew & Keifer

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	37	43
In Common Segment	16	30
Outside Common Segment	13	5
Wait Time	0	3
Walk Time	8	5
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	18.8	20.9
In Common Segment	36.0	24.0
Outside Common Segment	9.2	36.0



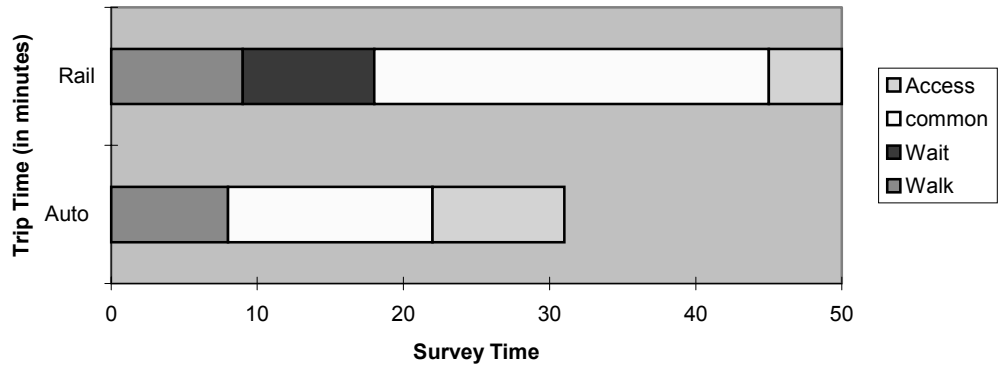
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE F6:
Mayhew & Keifer - 6th & H

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	30	52
In Common Segment	14	27
Outside Common Segment	8	4
Wait Time	0	10
Walk Time	8	11
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	23.2	17.3
In Common Segment	41.1	26.7
Outside Common Segment	15.0	45.0



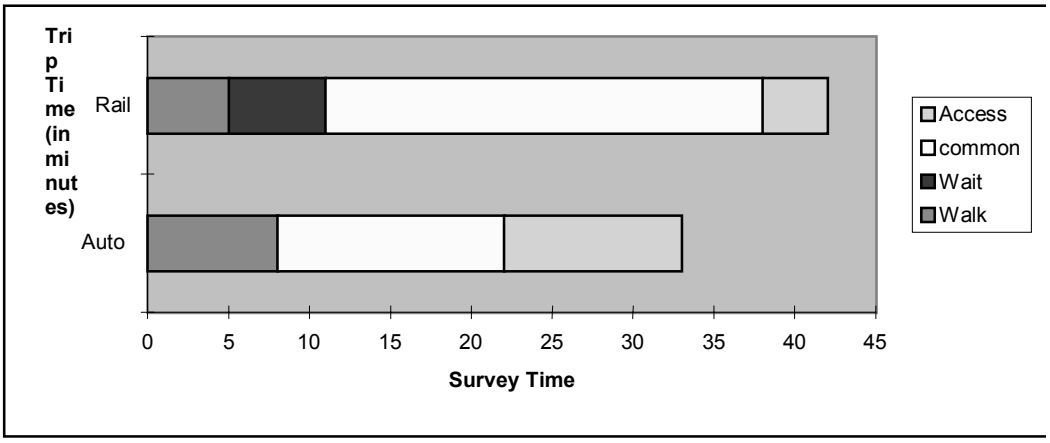
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE G7:
Keifer & Bradshaw - 8th & H

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	31	50
In Common Segment	14	27
Outside Common Segment	9	5
Wait Time	0	9
Walk Time	8	9
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	22.5	18.0
In Common Segment	41.1	26.7
Outside Common Segment	13.3	36.0



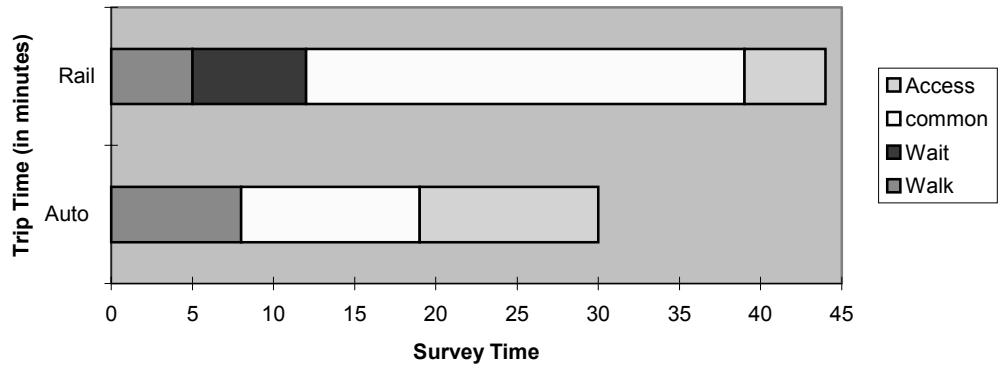
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE H8:
Rosemont & Huntsman - 9th & I

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	33	42
In Common Segment	14	27
Outside Common Segment	11	4
Wait Time	0	6
Walk Time	8	5
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	21.1	21.4
In Common Segment	41.1	26.7
Outside Common Segment	10.9	45.0



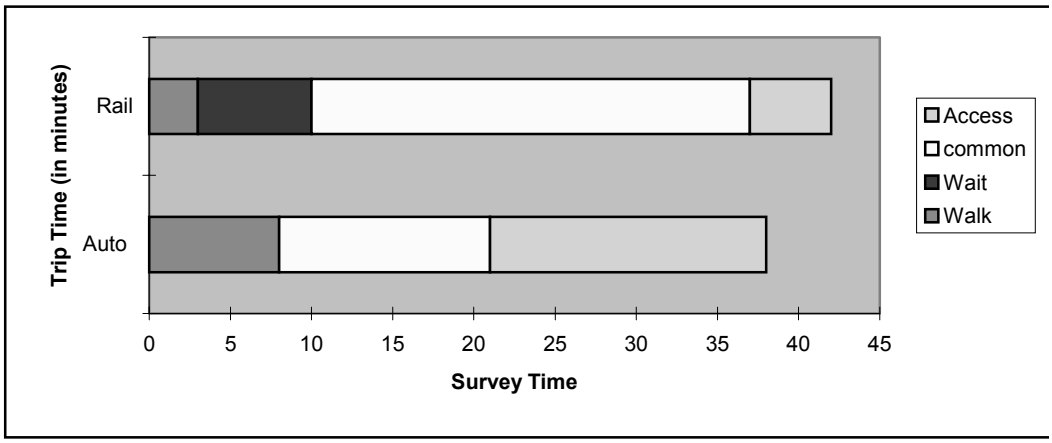
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE I9:
Keifer & Huntsman - 7th & I

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	30	44
In Common Segment	11	27
Outside Common Segment	11	5
Wait Time	0	7
Walk Time	8	5
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	23.2	20.5
In Common Segment	52.4	26.7
Outside Common Segment	10.9	36.0



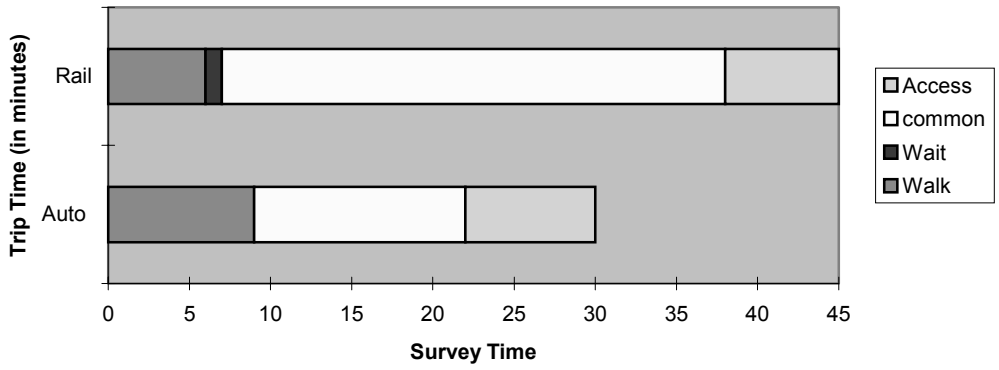
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE J10:
Folsom & Routier - 9 & L

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	38	42
In Common Segment	13	27
Outside Common Segment	17	5
Wait Time	0	7
Walk Time	8	3
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	18.3	21.4
In Common Segment	44.3	26.7
Outside Common Segment	7.1	36.0



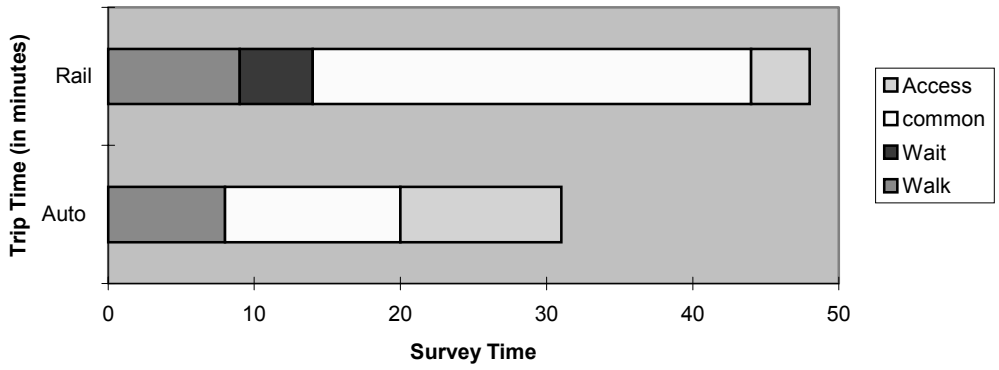
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 6G:
6th & H - Keifer & Bradshaw

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	30	45
In Common Segment	13	31
Outside Common Segment	8	7
Wait Time	0	1
Walk Time	9	6
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	23.2	20.0
In Common Segment	44.3	23.2
Outside Common Segment	15.0	25.7



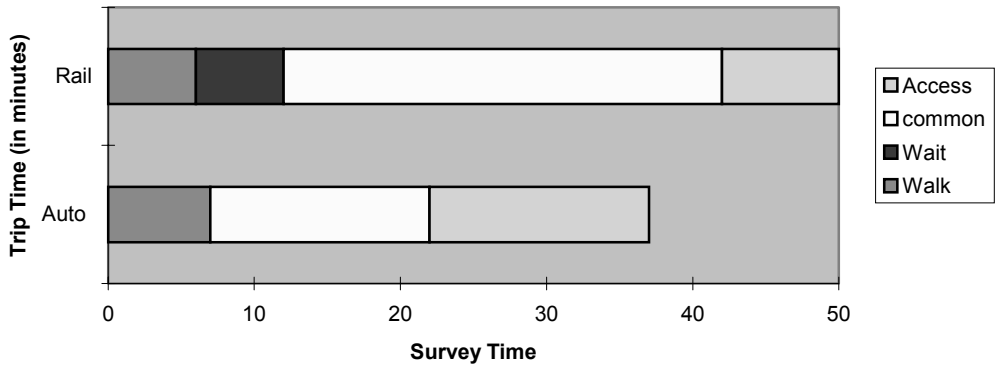
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 7H:
8th & H - Rosemont & Huntsman

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	31	48
In Common Segment	12	30
Outside Common Segment	11	4
Wait Time	0	5
Walk Time	8	9
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	22.5	18.8
In Common Segment	48.0	24.0
Outside Common Segment	10.9	45.0



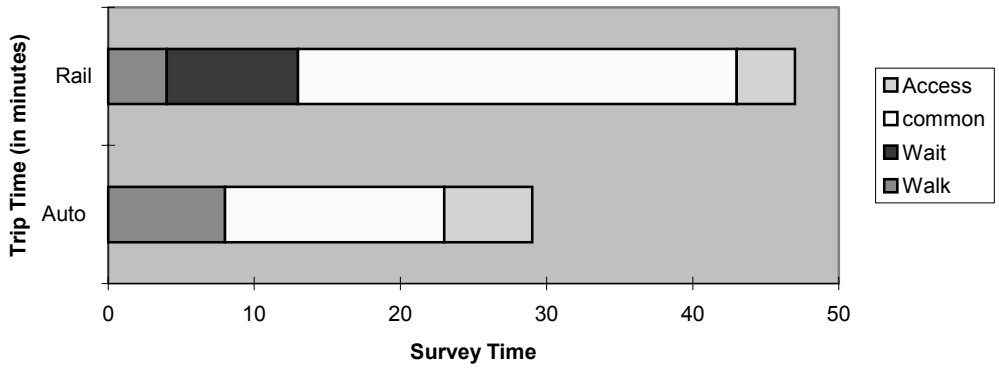
CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 8I:
9th & I - Keifer & Huntsman

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	37	50
In Common Segment	15	30
Outside Common Segment	15	8
Wait Time	0	6
Walk Time	7	6
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	18.8	18.0
In Common Segment	38.4	24.0
Outside Common Segment	8.0	22.5



CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE FOR
ROUTE 9J:
7th & I - Folsom & Routier

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	29	47
In Common Segment	15	30
Outside Common Segment	6	4
Wait Time	0	9
Walk Time	8	4
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	24.0	19.1
In Common Segment	38.4	24.0
Outside Common Segment	20.0	45.0



CORRIDOR: Butterfield - Sacramento
SUMMARY TABLE
ROUTE 10A:
9th & L - Old Placerville & Happy Ln

	SURVEY TYPE	
TIME (minutes)	Auto	Light Rail
Trip	31	47
In Common Segment	12	29
Outside Common Segment	11	9
Wait Time	0	3
Walk Time	8	6
DISTANCE (miles)		
Route Distance	11.6	15.0
Common Segment Distance	9.6	12.0
SPEED (mph)		
Trip	22.5	19.1
In Common Segment	48.0	24.8
Outside Common Segment	10.9	20.0